PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

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A3

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(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

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16 November 1989 (16.11.89)

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25 January 1990 (25.01.90)

(54) Title: METHOD AND APPARATUS FOR LASER SURGERY

(57) Abstract

Apparatus and method for laser surgery in which laser energy, pulsed or continuous, is focussed to a focus spot (FS) of a few microns which is located within tissue, or the like to cause highly localized heating. The pulsed radiation is in the TEM(oo) mode, has a wavelength of approximately 1064 nanometers, the pulses being not in excess of 100 nanoseconds and the pulse rate being approximately 2000 per second. Where the laser beam is continuous or pulsed, it has a wavelength of approximately 1400 to 1800 nanometers, or in photoablative modes, having a wavelength of 190 to about 300 nanometers. The focus spot (FS) may be caused to move relative to the axis of a handpiece (40) which delivers the laser energy to the body. Handpieces (20, 40) are provided in which laser energy is focussed to a focus spot (FS) of ten to thirty microns, and liquid is caused to flow across the exposure site to remove debris, a handpiece having a tubular terminal portion into which liquid is introduced, the distal end (54) of the handpiece having transverse channels (56) for the escape of liquid. A handpiece of the foregoing construction may have an endoscope including a glass contact tip (65) at its distal end and to receive light and to acquire an image of the exposure site. Probes for eye surgery include a quartz rod (82) in a sheath (84), the quartz rod (82) having a beveled distal end surface (83) through which the laser radiation is emitted. Probe has infusion (86) and aspiration (88) passages, the ends of which are coplanar with the beveled end surface (83) of the quartz rod (82).

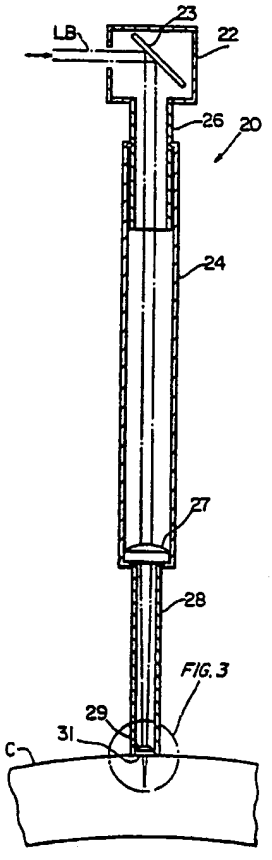

FIG. 3

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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SN	Senegal
SU	Soviet Union
TD	Chad
TG	Togo
US	United States of America

AMENDED CLAIMS

[received by the International Bureau on 26 December 1989 (26.12.89);
original claims 28,41 cancelled; claims 1,2,14-16,21,22,23-27,30-38, 40,42,45,47-49,
55-57,62-65, 67 amended ; new claims 68-71 added; other claims unchanged (11 pages)]

1. Apparatus for delivering laser energy comprising:

means for generating a laser beam,

a handpiece for receiving said laser beam having proximal and distal ends,

means in said handpiece for focussing said beam to a focus spot outwardly of said handpiece, having a diameter of a few microns and positioned a predetermined distance from said focussing means, whereby to effect modification of a site within a body through a portion of which said beam has passed.

2. The apparatus of claim 1, wherein said focussing means comprises means for focussing said focus spot approximately 0.5 - 0.5 millimeter from said focussing means.

3. The apparatus of claim 1, said laser beam generating means comprising means for generating a laser beam having a wavelength of approximately 1.0 to 2.0 microns.

4. The apparatus of claim 1, said generating means comprises means for generating a laser beam of TEM(oo) radiation.

5. The apparatus of claim 1, said generating means comprising means for generating a laser beam having a wavelength of approximately 1064 nanometer.

6. The apparatus of claim 5, said generating means generating a pulsed laser beam.

7. The apparatus of claim 6, said generating means comprising means for providing pulses having a duration of not substantially in excess of about 70 nanoseconds.

8. The apparatus of claim 7, said generating means comprising means for delivering said pulses at a rate of approximately 2,000 per second.

9. The apparatus of claim 1, said generating means comprising means for generating TEM(oo) radiation at approximately 1064 nanometer wavelength in pulses of not in excess of about 70 nanoseconds at a pulse rate of approximately 2000 per second.

10. The apparatus of claim 1, said generating means comprising means for generating a continuous laser beam.

11. The apparatus of claim 1, wherein said generating means comprises means for generating a continuous laser beam having a wavelength of approximately 1,400 to 1,800 nanometer.

12. The apparatus of claim 1, said means for generating a laser beam comprising excimer laser means for generating a photoablative laser beam having a wavelength of approximately 193-300 nanometers.

13. The apparatus of claim 1, said means for generating a laser beam comprising YAG laser means for generating pulsed radiation, and means for reducing the wavelength of the generated radiation.

14. The apparatus of claim 13, said wavelength reducing means comprising means for doubling said radiation.

15. The apparatus of claim 13, said wavelength reducing means comprising a crystal through which said radiation is passed.

16. The apparatus of claim 13, said wavelength reducing means comprising a second harmonic crystal and a fourth harmonic crystal positioned to successively receive radiation from said YAG laser.

17. The apparatus of claim 16, said second harmonic crystal being potassium titanium phosphate.

18. The apparatus of claim 17, said fourth harmonic crystal being beta barium borate.

19. The apparatus of claim 16, said fourth harmonic crystal being beta barium borate.

20. The apparatus of claim 1, said focussing means comprising a plano-convex lens.

21. The apparatus of claim 20, wherein said plano-convex lens is a sapphire lens in the distal end of said handpiece and the plano surface thereof being an exterior lens surface which is engageable with a body containing the locus of said focus spot.

22. The apparatus of claim 1, and further comprising means for moving said focus spot relative to the axis of said handpiece.

23. The apparatus of claim 22, said moving means comprising an optical wedge, and means for imparting rotational motion to said optical wedge.

24. The apparatus of claim 22, said moving means comprising an optical wedge and means for imparting oscillatory motion to said optical wedge.

25. Apparatus for performing laser surgery comprising:

a handpiece having proximal and distal ends,

means for introducing a laser beam into said proximal end,

means in said handpiece for focussing said beam to a focus spot including an objective lens at said distal end,

said handpiece having a tubular terminal portion, with an open distal end, said terminal portion extending beyond the distal end of said handpiece and coaxially with said objective lens for engaging a body, said objective lens being spaced from the distal end of said terminal portion, and

means for causing a flow of liquid through the tubular terminal portion and out of the distal end thereof,

whereby said objective lens is spaced a predetermined distance from said body and said laser beam passes through the liquid in said tubular terminal portion.

26. The apparatus of claim 25, wherein said distal end of said handpiece has a distal end surface for engagement with a body, said distal end surface having lateral escape channels therein.

27. The apparatus of claim 26, wherein said tubular terminal portion narrows towards said distal end.

29. The apparatus of claim 25, said generating means comprising means for generating ablative laser radiation, said apparatus further comprising means for delivering light to a body adjacent said handpiece, and means for acquiring an image of said body.

30. The apparatus of claim 29, said light delivering and image acquiring means comprising a transparent element at the distal end of said handpiece having distal end surface means for engaging a surface of said body.

31. The apparatus of claim 30, said handpiece having a longitudinal axis, said element having an internal reflective surface inclined relative to said longitudinal axis for reflecting light delivered to said element and for reflecting an image of said body.

32. The apparatus of claim 31, said light delivering means comprising optical fiber means for delivering light to said element, said optical fiber means having an end adjacent said element with the axis thereof laterally of said longitudinal axis.

33. The apparatus of claim 31, said image acquiring means comprising optical fiber means for receiving and transmitting an image of said body, said optical fiber means having an end adjacent said element with the axis thereof laterally of said longitudinal axis.

34. The apparatus of claim 30, said element being of substantially inelastic material and having a fluid passage therethrough extending transversely of said distal end surface, said handpiece comprising a tubular terminal portion with a distal end having said element thereon, means for introducing liquid into said tubular terminal portion remote from said element, said fluid passage in said element being in fluid communication

with the interior of said tubular terminal portion.

35. The apparatus of claim 34, wherein said passage of said element is a linearly extending passage substantially coaxial with the axis of said tubular terminal portion.

36. The apparatus of claim 34, said element having a distal surface and lateral channels in the distal surface thereof in communication with said passage.

37. Apparatus for delivery laser energy comprising:

a probe comprising a substantially cylindrical quartz rod having proximal and distal ends,

said quartz rod at the distal end thereof having a beveled end surface for emitting radiation, and

means for delivering a divergent beam of laser radiation to said proximal end of said quartz rod and for causing radiation to be conveyed through said rod by internal reflection,

whereby the radiation emitted from said quartz rod is sharply defined beyond said bevelled end surface.

38. The apparatus of claim 37, and further comprising:

means for causing fluid to flow across said beveled end surface of said rod comprising:

(a) means for discharging fluid from said probe at the distal end thereof, and

(b) means for aspirating fluid into the distal end of said probe.

39. The apparatus of claim 38, said means for discharging fluid from said probe comprising a discharge port which is beveled and lies in the same plane as the beveled end surface of said quartz rod.

40. The apparatus of claim 39, wherein said aspirating means includes an aspiration port which has a beveled end portion which lies in the same plane as the beveled end surface of said quartz rod, and

wherein said beveled end surface of said rod is between said ports.

42. The apparatus of claim 38, said probe comprising a tube, said quartz rod being in said tube, said fluid discharging means and said fluid aspirating means comprising passages in said tube adjacent said quartz rod, said quartz rod being between said passages.

43. The apparatus of claim 40, said tube being of silicon rubber.

44. The apparatus of claim 38, said tube being elliptical.

45. The apparatus of claim 38, said tube having said quartz rod centrally located therein.

46. The apparatus of claim 38, said tube having said quartz rod centrally located therein.

47. The apparatus of claim 39, said discharging means comprising a discharge tube.

48. A method of surgically cutting or modifying only tissue which is located at a short, predetermined distance from the surface thereof comprising:

providing a handpiece having a distal end with a lens at the distal end thereof,

placing against the surface of said tissue the lens of the distal end of said handpiece,

generating a laser beam,

passing said laser beam through said handpiece toward and through said and lens at said distal end and

thence into said tissue with said lens thereagainst, and

cutting or modifying only said tissue at a distance from said surface by focussing said laser beam to a focus spot

(a) having a diameter of a few microns and

(b) located a short distance into said tissue from the surface thereof.

49. The method of claim 48, wherein said generating is of a laser beam having a wavelength of about 2.0-2.0 microns.

50. The method of claim 49, wherein said generating is of pulses of laser radiation.

51. The method of claim 50, wherein said generated pulses having a duration of not substantially in excess of about 70 nanoseconds.

52. The method of claim 50, wherein said pulses are delivered at a rate of approximately 2,000 per second.

53. The method of claim 50, wherein said generating is of a laser beam having a wavelength of approximately 1064 nanometers.

54. The method of claim 50, wherein said generating is of a laser beam of TEM(oo) mode.

55. The method of claim 48, wherein said generating is of a laser beam of TEM(oo) mode.

56. The method of claim 48, wherein said generating is of pulses of a laser beam in the TEM(oo) mode, the laser beam having a wavelength of 0.2 to 2.0 microns, and the pulses having a duration of not

substantially in excess of about 70 nanoseconds and are delivered at a rate of approximately 2000 per second.

57. The method of claim 48, and further comprising moving said focus spot in said tissue.

58. The method of claim 57, wherein said moving is movement in an arcuate path.

59. The method of claim 59, wherein said movement is oscillatory movement.

60. The method of claim 51, wherein said generating is of a continuous laser beam.

61. The method of claim 48, wherein said generating is of a laser beam having a wavelength of approximately 1400 to 1800 nanometer.

62. A method of surgically cutting or modifying tissue comprising;

generating a laser beam of photoablative property, and

directing said beam into and partly through tissue and focussing said beam to a focus spot having a diameter of a few microns at an exposure site in said tissue a predetermined distance from the surface thereof.

63. A method of surgically cutting or modifying a body having a surface with an exposure site comprising:

generating a laser beam of photoablative property,

directing said laser beam into a handpiece having therein focussing means with an objective lens for forming a focus spot,

placing said lens a predetermined distance from said exposure site of said body such that said focus spot is at a predetermined position relative to said

exposure site, and

causing a stream of liquid to move across said exposure site.

64. The method of claim 63, providing a body of liquid between said objective lens and said exposure site, and passing said beam through said body of liquid.

65. The method of claim 64, and further comprising causing said body of liquid to flow towards said exposure site.

66. The method of claim 62, and further comprising directing light to said exposure site, and acquiring an image of said site at a location remote therefrom.

67. A method of treatment of the human body comprising:

generating a beam of laser radiation,

conducting said beam through a laser radiation transmitting rod having a distal end,

causing said beam to be internally reflected in said rod and to pass out of the distal end thereof,

focussing said beam at a location beyond the distal end of said rod, and

causing fluid to flow across said distal end of said rod.

68. The method of claim 46, wherein said placing against the surface of tissue is placing agianst the epithelium of a cornea, and said focussing of said laser beamis in the intrastromal layer, whereby to cause localized heationg of stromal fibers.

69. The method of claim 67, wherein said focussing of said laser beam is into the intrastromal layer of a cornea.

70. A method of modifying the stroma comprising:

generating a laser beam of photoablative property,

directing said laser beam into a cornea, and through a portion of the thickness thereof, and

focussing said laser beam to a focus spot having a diameter of a few microns, said focus spot being located in the intrastromal layer,

whereby only the intrastromal layer is modified by said laser beam.

71. A method of modifying the stroma comprising:

generating a laser beamof photoablative property.

focussing said laser beam to a focus spot having a diamter of a few microns, said focus spot being lcoated in the intrastormal layer.

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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H01S 3/00, A61B 1/06

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(43) International Publication Date: 27 July 1989 (27.07.89)

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(31) Priority Application Number: 148,425

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(33) Priority Country: US

(71) Applicant: REFRACTIVE LASER RESEARCH & DEVELOPMENT PROGRAM, LTD. [US/US]; 7810 Louis Pasteur, San Antonio, TX 78229 (US).

(72) Inventors: TABOADA, John ; 12530 Elm Country, San Antonio, TX 78230 (US). POIRIER, Robert, H. ; 3458 River Path, San Antonio, TX 78229 (US).

(74) Agent: LAVINE, Irvin, A.; Mason, Fenwick & Lawrence, 1225 Eye Street, N.W., Suite 1000, Washington, DC 20005 (US).

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Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(88) Date of publication of the international search report:
16 November 1989 (16.11.89)

(54) Title: METHOD AND APPARATUS FOR LASER SURGERY

(57) Abstract

Apparatus and method for laser surgery in which laser energy, pulsed or continuous, is focussed to a focus spot (FS) of a few microns which is located within tissue, or the like to cause highly localized heating. The pulsed radiation is in the TEM(oo) mode, has a wavelength of approximately 1064 nanometers, the pulses being not in excess of 100 nanoseconds and the pulse rate being approximately 2000 per second. Where the laser beam is continuous or pulsed, it has a wavelength of approximately 1400 to 1800 nanometers, or in photoablative modes, having a wavelength of 190 to about 300 nanometers. The focus spot (FS) may be caused to move relative to the axis of a handpiece (40) which delivers the laser energy to the body. Handpieces (20, 40) are provided in which laser energy is focussed to a focus spot (FS) of ten to thirty microns, and liquid is caused to flow across the exposure site to remove debris, a handpiece having a tubular terminal portion into which liquid is introduced, the distal end (54) of the handpiece having transverse channels (56) for the escape of liquid. A handpiece of the foregoing construction may have an endoscope including a glass contact tip (65) at its distal end and to receive light and to acquire an image of the exposure site. Probes for eye surgery include a quartz rod (82) in a sheath (84), the quartz rod (82) having a beveled distal end surface (83) through which the laser radiation is emitted. Probe has infusion (86) and aspiration (88) passages, the ends of which are coplanar with the beveled end surface (83) of the quartz rod (82).

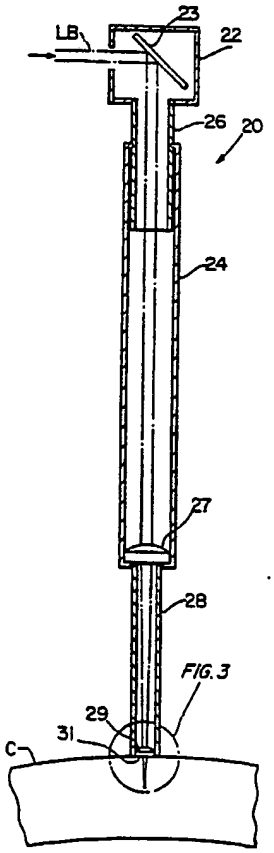

FIG. 3

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TG	Togo
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INTERNATIONAL SEARCH REPORT

International Application No PCT/US 89/00156

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: A 61 B 17/36, A 61 F 9/00, A 61 C 1/00, B 23 K 26/00, H 01 S 3/00, A 61 B 1/06

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[4]	A 61 B, A 61 F

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 4638800 (MICHEL) 27 January 1987, see column 1, lines 46-49; column 3, lines 9-11; column 5, lines 1-36; column 6, lines 4-47; column 7, lines 19-30; column 7, line 49 - column 8, line 3; column 9, lines 9-39; column 13, lines 50-58; column 14, lines 5-16; column 15, line 65 - column 16, line 4; column 16, line 44 - column 17, line 15; column 18, lines 3-40; figures 1,3,8	1,2,4,10,29
Y		3,5-7,12-17, 20
A		6,22
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Y	WO, A, 87/00748 (ARON-ROSA) 12 February 1987, see page 1, lines 1-36; page 2, lines 20-24; page 6, line 31 - page 7, line 9; page 8, lines 1-8; page 9, lines 4-15; page 10, lines 11-15; page 10, line 32 - page 15, line 16; claim 6; figures	3,5-7,12-17

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* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
29th September 1989	26. 10. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	T.K. WILLIS

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A		1,8-11,18,19, 29
Y	US, A, 4397310 (POMERANTZEFF) 9 August 1983, see column 2, lines 43-61; column 3, line 27 - column 4, line 34; column 5, lines 48-55; figures 1-4	20
A		1,2,10,29, 32
Y	US, A, 3865113 (SHARON) 11 February 1975, see column 1, lines 8-11; column 3, lines 17-53; column 5, lines 48-56; figures 1,12	1-7,20
Y	WO, A, 84/04211 (M.T.A.K.F.K.I.) 25 October 1984, see page 1, lines 10, 11; page 2, lines 1-4, 24-30; page 3, lines 25-27	1-7,20
A		9,13
A	US, A, 3720213 (HOBART) 13 March 1973, see column 2, lines 43-47; column 4, lines 4-27; column 5, line 53 - column 6, line 15; figures 1,3,4A	1,4,21,30
A	EP, A, 0196519 (C.H.M.C.) 8 October 1986, see page 8, lines 3-13; figure 2	1,2
A	EP, A, 0248520 (E.R.I.O.T.R.F.) 9 December 1987, see column 6, lines 18-26; figures 8A, 8B	1,2
A	US, A, 3750670 (PALANOS) 7 August 1973, see column 3, lines 3-28; column 4, lines 9-37; figures	3,5,10, 13-15,18,19
A	US, A, 4122853 (SMITH) 31 October 1978, see column 2, line 51 - column 3, line 52; column 4, line 57 - column 5, line 64; figures (cited in the application)	22,23,25, 29,32
A	US, A, 4583539 (KARLIN) 22 April 1986, see column 7, lines 5-11; column 8, line 12 - column 9, line 2; column 9, line 37 - column 10, line 58; abstract; figures	22,25,27,29, 32,33,37,38, 42,44-47
A	US, A, 4694828 (EICHENBAUM) 22 September 1987, see column 3, line 65 - column 7, line 15; figures	25,37,38,42, 45-47

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	DE, A, 3612287 (MEDITEC) 15 October 1987, see column 5, lines 50-54; figures	26,36
A	US, A, 4597380 (RAIF) 1 July 1986, see column 2, line 33 - column 4, line 20; figures	29,32
A	US, A, 4211229 (WURSTER) 8 July 1980, see abstract; figures	29
A	DE, A, 2202120 (CARL ZEISS) 26 July 1973, see page 6, lines 16-28; figures	30,31
A	EP, A, 0230094 (KOWA) 29 July 1987	
A	US, A, 4326529 (DOSS) 27 April 1982 (cited in the application)	

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☒ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☒ Claim numbers *, because they relate to subject matter not required to be searched by this Authority, namely:

* 48-67 See PCT-Rule 39.1(IV): Methods for treatment of the human or animal body by surgery or therapy, as well as diagnostic methods.

2. ☐ Claim numbers....., because they relate to parts of the International application that do not comply with the prescribed requirements to such an extent that no meaningful International search can be carried out, specifically:

3. ☐ Claim numbers....., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

See PCT/ISA/206 sent to you on 7th June 1989.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the International application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☒ No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 8900156 SA 26744

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 24/10/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 4638800	27-01-87	None		
WO-A- 8700748	12-02-87	FR-A-	2585558	06-02-87
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 24/10/89
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(54) Title: METHOD AND APPARATUS FOR LASER SURGERY

(57) Abstract

Apparatus and method for laser surgery in which laser energy, pulsed or continuous, is focussed to a focus spot (FS) of a few microns which is located within tissue, or the like to cause highly localized heating. The pulsed radiation is in the TEM(oo) mode, has a wavelength of approximately 1064 nanometers, the pulses being not in excess of 100 nanoseconds and the pulse rate being approximately 2000 per second. Where the laser beam is continuous or pulsed, it has a wavelength of approximately 1400 to 1800 nanometers, or in photoablative modes, having a wavelength of 190 to about 300 nanometers. The focus spot (FS) may be caused to move relative to the axis of a handpiece (40) which delivers the laser energy to the body. Handpieces (20, 40) are provided in which laser energy is focussed to a focus spot (FS) of ten to thirty microns, and liquid is caused to flow across the exposure site to remove debris, a handpiece having a tubular terminal portion into which liquid is introduced, the distal end (54) of the handpiece having transverse channels (56) for the escape of liquid. A handpiece of the foregoing construction may have an endoscope including a glass contact tip (65) at its distal end and to receive light and to acquire an image of the exposure site. Probes for eye surgery include a quartz rod (82) in a sheath (84), the quartz rod (82) having a beveled distal end surface (83) through which the laser radiation is emitted. Probe has infusion (86) and aspiration (88) passages, the ends of which are coplanar with the beveled end surface (83) of the quartz rod (82).

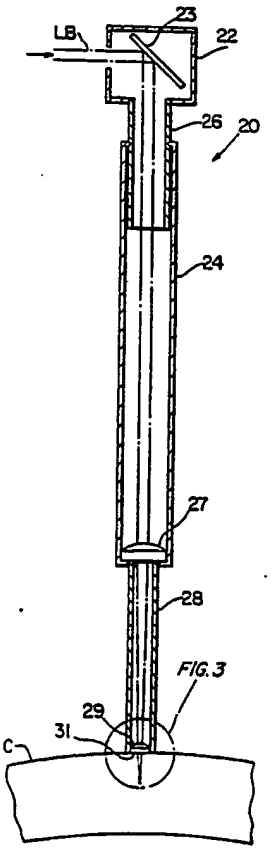

FIG. 3

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AMENDED CLAIMS

[received by the International Bureau on 26 December 1989 (26.12.89);
original claims 28,41 cancelled; claims 1,2,14-16,21,22,23-27,30-38, 40,42,45,47-49,
55-57,62-65, 67 amended ; new claims 68-71 added; other claims unchanged (11 pages)]

1. Apparatus for delivering laser energy comprising:

means for generating a laser beam,

a handpiece for receiving said laser beam having proximal and distal ends,

means in said handpiece for focussing said beam to a focus spot outwardly of said handpiece, having a diameter of a few microns and positioned a predetermined distance from said focussing means, whereby to effect modification of a site within a body through a portion of which said beam has passed.

2. The apparatus of claim 1, wherein said focussing means comprises means for focussing said focus spot approximately 0.5 - 0.5 millimeter from said focussing means.

3. The apparatus of claim 1, said laser beam generating means comprising means for generating a laser beam having a wavelength of approximately 1.0 to 2.0 microns.

4. The apparatus of claim 1, said generating means comprises means for generating a laser beam of TEM(oo) radiation.

5. The apparatus of claim 1, said generating means comprising means for generating a laser beam having a wavelength of approximately 1064 nanometer.

6. The apparatus of claim 5, said generating means generating a pulsed laser beam.

7. The apparatus of claim 6, said generating means comprising means for providing pulses having a duration of not substantially in excess of about 70 nanoseconds.

8. The apparatus of claim 7, said generating means comprising means for delivering said pulses at a rate of approximately 2,000 per second.

9. The apparatus of claim 1, said generating means comprising means for generating TEM(oo) radiation at approximately 1064 nanometer wavelength in pulses of not in excess of about 70 nanoseconds at a pulse rate of approximately 2000 per second.

10. The apparatus of claim 1, said generating means comprising means for generating a continuous laser beam.

11. The apparatus of claim 1, wherein said generating means comprises means for generating a continuous laser beam having a wavelength of approximately 1,400 to 1,800 nanometer.

12. The apparatus of claim 1, said means for generating a laser beam comprising excimer laser means for generating a photoablative laser beam having a wavelength of approximately 193-300 nanometers.

13. The apparatus of claim 1, said means for generating a laser beam comprising YAG laser means for generating pulsed radiation, and means for reducing the wavelength of the generated radiation.

14. The apparatus of claim 13, said wavelength reducing means comprising means for doubling said radiation.

15. The apparatus of claim 13, said wavelength reducing means comprising a crystal through which said radiation is passed.

16. The apparatus of claim 13, said wavelength reducing means comprising a second harmonic crystal and a fourth harmonic crystal positioned to successively receive radiation from said YAG laser.

17. The apparatus of claim 16, said second harmonic crystal being potassium titanium phosphate.

18. The apparatus of claim 17, said fourth harmonic crystal being beta barium borate.

19. The apparatus of claim 16, said fourth harmonic crystal being beta barium borate.

20. The apparatus of claim 1, said focussing means comprising a plano-convex lens.

21. The apparatus of claim 20, wherein said plano-convex lens is a sapphire lens in the distal end of said handpiece and the plano surface thereof being an exterior lens surface which is engageable with a body containing the locus of said focus spot.

22. The apparatus of claim 1, and further comprising means for moving said focus spot relative to the axis of said handpiece.

23. The apparatus of claim 22, said moving means comprising an optical wedge, and means for imparting rotational motion to said optical wedge.

24. The apparatus of claim 22, said moving means comprising an optical wedge and means for imparting oscillatory motion to said optical wedge.

25. Apparatus for performing laser surgery comprising:

a handpiece having proximal and distal ends,

means for introducing a laser beam into said proximal end,

means in said handpiece for focussing said beam to a focus spot including an objective lens at said distal end,

said handpiece having a tubular terminal portion, with an open distal end, said terminal portion extending beyond the distal end of said handpiece and coaxially with said objective lens for engaging a body, said objective lens being spaced from the distal end of said terminal portion, and

means for causing a flow of liquid through the tubular terminal portion and out of the distal end thereof,

whereby said objective lens is spaced a predetermined distance from said body and said laser beam passes through the liquid in said tubular terminal portion.

26. The apparatus of claim 25, wherein said distal end of said handpiece has a distal end surface for engagement with a body, said distal end surface having lateral escape channels therein.

27. The apparatus of claim 26, wherein said tubular terminal portion narrows towards said distal end.

29. The apparatus of claim 25, said generating means comprising means for generating ablative laser radiation, said apparatus further comprising means for delivering light to a body adjacent said handpiece, and means for acquiring an image of said body.

30. The apparatus of claim 29, said light delivering and image acquiring means comprising a transparent element at the distal end of said handpiece having distal end surface means for engaging a surface of said body.

31. The apparatus of claim 30, said handpiece having a longitudinal axis, said element having an internal reflective surface inclined relative to said longitudinal axis for reflecting light delivered to said element and for reflecting an image of said body.

32. The apparatus of claim 31, said light delivering means comprising optical fiber means for delivering light to said element, said optical fiber means having an end adjacent said element with the axis thereof laterally of said longitudinal axis.

33. The apparatus of claim 31, said image acquiring means comprising optical fiber means for receiving and transmitting an image of said body, said optical fiber means having an end adjacent said element with the axis thereof laterally of said longitudinal axis.

34. The apparatus of claim 30, said element being of substantially inelastic material and having a fluid passage therethrough extending transversely of said distal end surface, said handpiece comprising a tubular terminal portion with a distal end having said element thereon, means for introducing liquid into said tubular terminal portion remote from said element, said fluid passage in said element being in fluid communication

with the interior of said tubular terminal portion.

35. The apparatus of claim 34, wherein said passage of said element is a linearly extending passage substantially coaxial with the axis of said tubular terminal portion.

36. The apparatus of claim 34, said element having a distal surface and lateral channels in the distal surface thereof in communication with said passage.

37. Apparatus for delivery laser energy comprising:

a probe comprising a substantially cylindrical quartz rod having proximal and distal ends,

said quartz rod at the distal end thereof having a beveled end surface for emitting radiation, and

means for delivering a divergent beam of laser radiation to said proximal end of said quartz rod and for causing radiation to be conveyed through said rod by internal reflection,

whereby the radiation emitted from said quartz rod is sharply defined beyond said bevelled end surface.

38. The apparatus of claim 37, and further comprising:

means for causing fluid to flow across said beveled end surface of said rod comprising:

(a) means for discharging fluid from said probe at the distal end thereof, and

(b) means for aspirating fluid into the distal end of said probe.

39. The apparatus of claim 38, said means for discharging fluid from said probe comprising a discharge port which is beveled and lies in the same plane as the beveled end surface of said quartz rod.

40. The apparatus of claim 39, wherein said aspirating means includes an aspiration port which has a beveled end portion which lies in the same plane as the beveled end surface of said quartz rod, and

wherein said beveled end surface of said rod is between said ports.

42. The apparatus of claim 38, said probe comprising a tube, said quartz rod being in said tube, said fluid discharging means and said fluid aspirating means comprising passages in said tube adjacent said quartz rod, said quartz rod being between said passages.

43. The apparatus of claim 40, said tube being of silicon rubber.

44. The apparatus of claim 38, said tube being elliptical.

45. The apparatus of claim 38, said tube having said quartz rod centrally located therein.

46. The apparatus of claim 38, said tube having said quartz rod centrally located therein.

47. The apparatus of claim 39, said discharging means comprising a discharge tube.

48. A method of surgically cutting or modifying only tissue which is located at a short, predetermined distance from the surface thereof comprising:

providing a handpiece having a distal end with a lens at the distal end thereof,

placing against the surface of said tissue the lens of the distal end of said handpiece,

generating a laser beam,

passing said laser beam through said handpiece toward and through said and lens at said distal end and

thence into said tissue with said lens thereagainst, and

cutting or modifying only said tissue at a distance from said surface by focussing said laser beam to a focus spot

(a) having a diameter of a few microns and

(b) located a short distance into said tissue from the surface thereof.

49. The method of claim 48, wherein said generating is of a laser beam having a wavelength of about 2.0-2.0 microns.

50. The method of claim 49, wherein said generating is of pulses of laser radiation.

51. The method of claim 50, wherein said generated pulses having a duration of not substantially in excess of about 70 nanoseconds.

52. The method of claim 50, wherein said pulses are delivered at a rate of approximately 2,000 per second.

53. The method of claim 50, wherein said generating is of a laser beam having a wavelength of approximately 1064 nanometers.

54. The method of claim 50, wherein said generating is of a laser beam of TEM(oo) mode.

55. The method of claim 48, wherein said generating is of a laser beam of TEM(oo) mode.

56. The method of claim 48, wherein said generating is of pulses of a laser beam in the TEM(oo) mode, the laser beam having a wavelength of 0.2 to 2.0 microns, and the pulses having a duration of not

substantially in excess of about 70 nanoseconds and are delivered at a rate of approximately 2000 per second.

57. The method of claim 48, and further comprising moving said focus spot in said tissue.

58. The method of claim 57, wherein said moving is movement in an arcuate path.

59. The method of claim 59, wherein said movement is oscillatory movement.

60. The method of claim 51, wherein said generating is of a continuous laser beam.

61. The method of claim 48, wherein said generating is of a laser beam having a wavelength of approximately 1400 to 1800 nanometer.

62. A method of surgically cutting or modifying tissue comprising;

generating a laser beam of photoablative property, and

directing said beam into and partly through tissue and focussing said beam to a focus spot having a diameter of a few microns at an exposure site in said tissue a predetermined distance from the surface thereof.

63. A method of surgically cutting or modifying a body having a surface with an exposure site comprising:

generating a laser beam of photoablative property,

directing said laser beam into a handpiece having therein focussing means with an objective lens for forming a focus spot,

placing said lens a predetermined distance from said exposure site of said body such that said focus spot is at a predetermined position relative to said

exposure site, and

causing a stream of liquid to move across said exposure site.

64. The method of claim 63, providing a body of liquid between said objective lens and said exposure site, and passing said beam through said body of liquid.

65. The method of claim 64, and further comprising causing said body of liquid to flow towards said exposure site.

66. The method of claim 62, and further comprising directing light to said exposure site, and acquiring an image of said site at a location remote therefrom.

67. A method of treatment of the human body comprising:

generating a beam of laser radiation,

conducting said beam through a laser radiation transmitting rod having a distal end,

causing said beam to be internally reflected in said rod and to pass out of the distal end thereof,

focussing said beam at a location beyond the distal end of said rod, and

causing fluid to flow across said distal end of said rod.

68. The method of claim 46, wherein said placing against the surface of tissue is placing agianst the epithelium of a cornea, and said focussing of said laser beamis in the intrastromal layer, whereby to cause localized heationg of stromal fibers.

69. The method of claim 67, wherein said focussing of said laser beam is into the intrastromal layer of a cornea.

70. A method of modifying the stroma comprising:

generating a laser beam of photoablative property,

directing said laser beam into a cornea, and through a portion of the thickness thereof, and

focussing said laser beam to a focus spot having a diameter of a few microns, said focus spot being located in the intrastromal layer,

whereby only the intrastromal layer is modified by said laser beam.

71. A method of modifying the stroma comprising:

generating a laser beamof photoablative property.

focussing said laser beam to a focus spot having a diamter of a few microns, said focus spot being lcoated in the intrastormal layer.